DEVELOPMENT OF
AN INTEGRAL, NEOPRENE-COATED, ALUMINIZED, ASBESTOS CLOTH FOR FIRE FIGHTERS' SHIPBOARD COVERALLS

NAVY CLOTHING AND TEXTILE RESEARCH UNIT
NATICK, MASSACHUSETTS

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TECHNICAL REPORT NO. 103

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Navy Clothing and Textile Research Unit, Natick Laboratories, Natick, Massachusetts 01760	2a. REPORT SECURITY CLASSIFICATION: UNCLASSIFIED
	2b. GROUP

3. REPORT TITLE

DEVELOPMENT OF AN INTEGRAL, NEOPRENE-COATED, ALUMINIZED, ASBESTOS CLOTH FOR FIREFIGHTERS' SHIPBOARD COVERALLS

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Technical Report

5. AUTHOR(S) (First name, middle initial, last name)

Zelig Kupferman

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
August 1972	18	11

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S): 103
b. PROJECT NO. 523-003-11	
c.	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report): 4-71
d.	

10. DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY: Navy Clothing and Textile Research Unit, Natick Laboratories, Natick, Massachusetts 01760

13. ABSTRACT

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DD FORM 1 NOV 65 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

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UNCLASSIFIED

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
1.2-Pound Asbestos Cloth						
Neoprene Coating						
Aluminization						
11-Ounce Glass/Asbestos Fabric						
Durability						
Stiffness						
Water Resistance						
Tear Strength						

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523-003-11

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ABSTRACT

The Navy Clothing and Textile Research Unit (NCTRU) has developed an improved, neoprene-coated, aluminized, 1.2-pound asbestos (underwriter's grade) cloth to replace the neoprene-coated, aluminized, 11-ounce, glass/asbestos, cotton fabric for use in shipboard firefighter's coveralls. In prior testing, the neoprene-coated, aluminized, 1.2-pound asbestos cloth demonstrated significant improvements over the neoprene-coated, aluminized, 11-ounce, glass/asbestos, cotton fabric in both durability of the basic cloth and abrasion resistance of the aluminum coating. The anticipated problems of excessive stiffness and weight and reduced tear strength that an integral neoprene coating would cause for the aluminized, 1.2-pound asbestos fabric did not occur. The improved cloth showed only a slight increase in neoprene coating weight and stiffness. Adequate water resistance was obtained while the tear strength was not compromised as compared with the non-neoprene-coated, aluminized, 1.2-pound asbestos cloth. Garments made from this improved cloth were found to be satisfactory by firefighters for the desired end use. Test results also justify the use of this cloth as a replacement for the neoprene-coated, aluminized, 11-ounce, glass/asbestos, cotton fabric, used in firefighter's coveralls.

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INTRODUCTION

A neoprene coating has been successfully applied to the back of an aluminized, 1.2-pound, asbestos, herringbone-twill cloth for use in firefighter's shipboard coveralls. The Navy Clothing and Textile Research Unit (NCTRU) developed the cloth at the request of the Naval Supply Systems Command to replace the neoprene-coated, aluminized, 11-ounce, glass/asbestos, cotton fabric (1).

Without the neoprene coating the aluminized, 1.2-pound, asbestos, herringbone-twill cloth had demonstrated an ability to significantly extend the durability of both the basic fabric and the aluminum coating of proximity firefighter's clothing (2). (A separate vapor barrier lining (neoprene-coated nylon taffeta) was used with this cloth in place of an integral neoprene coating to protect the firefighter against steam burns.) Laboratory evaluation of the 1.2-pound, aluminized, asbestos cloth with the integral neoprene coating has shown it to possess acceptable levels of weight, stiffness and water resistance without loss in tear strength. Consequently, the use of this cloth as a replacement for the neoprene-coated, aluminized, 11-ounce, glass/asbestos, cotton fabric, used in firefighter's coveralls, is justified by the results.

This report deals with the evaluation of various weights (ounces per square yard) of neoprene applied to the back of three types of aluminized, 1.2-pound, asbestos, herringbone-twill cloths. Specifically, it studies the effects of an integral neoprene coating on the physical properties of these aluminized cloths and the suitability of the neoprene coating for use as a vapor barrier to protect the firefighter from steam burns.

BACKGROUND

The neoprene-coated, aluminized, 11-ounce, glass/asbestos, cotton fabric was developed by the Navy for use in two-piece garments (coats and trousers) to be worn at Naval Air Stations and in coveralls to be worn aboard aircraft carriers for pilot rescue in crash situations. The coveralls were also used for damage-control purposes aboard ship.

The basic fabric consisted of an all-glass fiber warp and a ply-yarn filling of asbestos/cotton plied with a glass fiber. The face of the fabric had a highly reflective vacuum-deposited aluminum surface, which permitted limited exposure in close proximity to a fire, thus allowing the firefighter to effect a rescue or to enter hot spaces during shipboard fires. The back of the fabric was coated with a fire-retardant neoprene coating, which functioned as a vapor barrier protecting the wearer from possible steam burns and preventing the basic fabric from rapidly wicking up flammable fuels (3).

Garments employing this aluminized, glass/asbestos fabric were in the supply system for a short time before unsatisfactory reports were received. The firefighters complained of cracking at extreme flex points (knees and elbows), edge abrasion, rips and tears, which were directly attributed to the large percentage of glass yarn (Figure 1). (Low flex and abrasion resistance are characteristics of glass fabric.) In addition, the aluminum coating exhibited poor abrasion resistance, resulting in a rapid loss of infrared reflectance. This loss was caused by the extreme thinness of the aluminum coating, which was inherent in the method of manufacture.

After the U. S. Naval Supply Research and Development Facility, the predecessor of NCTRU, received the task of engineering a new cloth, significant advancements were achieved. Abrasion-resistant aluminum coatings were developed which significantly increased the cloth's ability to retain its reflective properties. Concurrently, improved durability of the basic fabric was attained by replacement of the glass/asbestos cotton fabric with a 1.2-pound (underwriter's grade), asbestos, herringbone-twill cloth. (This improved aluminized cloth is currently used as the outer shell for the two-piece proximity firefighter's garment (4, 5). Technical requirements for the cloth are listed in reference 6.)

Because of the added thickness and weight of the 1.2-pound, asbestos cloth, it was originally thought expedient to utilize a separate vapor barrier, neoprene-coated, nylon-taffeta fabric, for the two-piece garment, instead of the integral neoprene coating employed in the lighter weight, glass/asbestos, cotton fabric to achieve adequate water resistance. It was visualized that the application of an integral neoprene coating would result in excessive stiffness and an unacceptable increase in coating weight on the rough-textured asbestos cloth. It was also foreseen that a loss in tear strength would result. However, in view of the savings in both material and manufacturing costs that would be realized by the use of an integral neoprene coating, this approach was investigated for the shipboard coverall cloth to determine the extent of the anticipated problems.

MATERIALS

An earlier report on heat reflective fabrics covered the development of an aluminized, 1.2-pound, asbestos, herringbone-twill cloth (2). This cloth exhibited a significant improvement over the neoprene-coated, aluminized, 11-ounce, glass/asbestos, cotton fabric, both in durability of the basic fabric and of the aluminum coating. (This cloth, currently used as the outer shell for firefighter's coat and trousers, is covered by reference 6.) Accordingly, for the development of a more durable shipboard coverall fabric, similar asbestos cloths and abrasion-resistant aluminum coatings were used. The basic, 1.2-pound (underwriter's grade), asbestos, herringbone-twill cloth was selected because it was non-flammable, durable and commercially available. (The designation, underwriter's grade, indicates that the fabric contains from 15-to-20-percent cotton, which is used as a carrier in spinning the asbestos yarns.)

Abrasion-resistant aluminum coatings are currently being applied to the cloth by two methods for use in Government garment contracts. In Method I aluminization, a 1/4-mil polyester film about 41 inches wide in continuous roll form is passed through a chamber which vacuum deposits an aluminum coating on one surface. The process is then repeated on the reverse side. Next, the double-coated film is permanently laminated to the basic fabric by means of special adhesives.

With Method II aluminization, the aluminum coating is deposited on one side of a continuous roll of acetate film and then a heat-sensitive adhesive is applied over the vacuum-deposited aluminum coating. Finally, the aluminized "transfer film" is laminated to the face of the asbestos fabric. This aluminization method differs from the preceding technique in that the acetate film is stripped from the aluminized fabric and discarded. In their final form both types of aluminum coatings attain a high degree of abrasion resistance. The flame-retardant-treated neoprene coating, normally applied before all aluminization, is applied to the cloth in such a manner as to be compatible with the basic cloth and to assure a quality coating.

The finished, coated fabric is intended to be used in a heat protective, life-saving coverall, without the addition of insulation. Thus, it is crucial that the component coatings be properly prepared and applied.

The following fabrics (see Tables I, II and III) were selected for the development work discussed in this report. (It should be noted that the listed fabrics are not samples but represent minimum 40-yard rolls.)

1. Fabrics A and B are 1.2-pound (underwriter's grade), asbestos, 3/1 herringbone twill, reversing on 15 ends and containing 35 ends by 27 picks per inch. The Method II abrasion-resistant aluminum coating was applied to the face, with an integral neoprene coating applied to the back before aluminization. (Temperature, pressure, time and coating formulations were kept to very close tolerances.)

2. Fabric C was manufactured in a similar manner to Fabrics A and B, except that the basic fabric contains a fire-retardant finish for the flammable cotton content (80% asbestos/20% cotton). This finish is required for the outer shell fabric of the firefighter's coat and trousers.

3. Fabric D, employing Method I aluminization, is similar to Fabrics A and B in basic fabric and neoprene coating. Abrasion resistance to the aluminum coating is obtained by the use of a plastic film overlay, which also enhances other properties of the coated asbestos fabric. If the film is not properly applied, however, it will "pop off" when subjected to a combination of humidity, temperature, chemicals, etc., during use.

4. Fabric E, which also employs Method I aluminization, contains the asbestos fabric and the neoprene coating conforming to Fabrics A and B. The plastic film is retained in like manner and for the same purpose as Fabric D--to impart abrasion resistance to the aluminum coating.

5. Fabric F, Coverall Fabric, conforms to Military Specification MIL-C-21890 and contains an integral neoprene coating on the back. It should be noted that the Military specification does not require a "Reflectivity After Abrasion" test. This fabric, which contains a glass warp and a glass-plied asbestos/cotton filling, was included as a control.

6. Fabric G, Standard Coat and Trousers Fabric, is the same as Fabric C (fire-retardant finish) but does not have an integral neoprene coating on the back. The aluminized fabric, used in the garment with a separate vapor-barrier fabric, is covered by reference 6. It was included as an additional control fabric.

TEST METHODS

Tests referred to in Tables I, II and III are those described in references 6 and 7, as follows:

Weight	Test Method 5041
Texture	Test Method 5050
Breaking strength, grab	Test Method 5100
Tear strength, Elmendorf	Test Method 5132
Flame resistance, vertical	Test Method 5903T
Stiffness, bending moment	Test Method 5202
Blocking (heat resistance)	Test Method 5872
Water resistance	Test Method 5512
Water resistance after low temperature	Test Method 5874 & 5512
Water resistance after adhesion of coating	Test Method 5972 & 5512
Reflectivity after abrasion	MIL-C-82249B
Adhesion of aluminum coating	MIL-C-82249B
Resistance to low temperature	MIL-C-82249B

Table I. Laboratory Data Showing Stiffness of Selected Fabrics[1]

Fabrics	Neoprene Coating Weight (oz/yd^2)	Stiffness[2] (inch-pounds)	
		Warp	Filling
A	4.1	0.051	0.047
B	6.0	0.032	0.034
C[3]	7.7	0.082	0.076
D	5.1	0.056	0.063
E	4.8	0.068	0.056
F	4.0	0.019	0.008
G	-	0.035	0.031

[1]Each figure represents an average of 10 readings.

[2]Moment weight--0.155 pound.

[3]Fire-retardant finish.

Table II. Laboratory Data Showing Water Resistance of Selected Fabrics[1]

Fabrics	Neoprene Coating Weight (oz/yd^2)	Water Resistance (PSI)[2]		
		Initial	After Low Temperature[3]	After Adhesion of Coating
A	4.1	105	42	91
B	6.0	70	14	15
C	7.7	88	28	72
D[4]	5.1	269	70	269
E[4]	4.8	214	38	208
F	4.0	110	77	42

[1]Each figure represents an average of five readings.

[2]Fabrics tested with aluminum side facing water.

[3]-20°F for one hour.

[4]Plastic film overlay.

Table III. Laboratory Evaluation of Selected Aluminized Fabrics

Fabrics	A	B	C	D	E	F	G
Weight, oz/yd^2	26.0	27.1	29.6	27.5	29.3	17.7	22.4
Weight of neoprene approximately, oz/yd^2	4.1	6.0	7.7	5.1	4.8	4.0	-
Break, grab, lbs.	128x93	117x81	138x103	157x139	158x120	121x129	138x99
Tear, Elmendorf, lbs.	11.2x8.0	11.7x9.5	8.2x6.3	9.7x8.1	10.1x7.8	3.8x9.3	9.9x8.7
Adhesion of coating	Pass	Pass	Pass	Pass	Pass	Pass	Pass
Blocking	Pass	Pass	Pass	Pass	Pass	Pass	Pass
Resistance to low temp.	Crazing	Crazing	Crazing	Pass	Pass	Pass	Crazing
Reflectivity after abrasion	Pass	Pass	Pass	Pass	Pass	Failure	Pass
Flame resistance, vertical, warp							
After flame, sec.	3.8	0.1	0.1	0.5	1.0	0	0
Char length, in.	0	0	0	0	0	1.5	0

DISCUSSION OF RESULTS

Durability

As reported in reference 2, improvement over the aluminized, 11-ounce, glass/asbestos fabric was accomplished in both the durability of the base fabric and the aluminum coating. That report includes data from laboratory evaluations and field trials. Improvements occurred when the basic glass/asbestos fabric was replaced by the more durable 1.2-pound, asbestos, herringbone-twill fabric, which greatly extended the use-life of the basic fabric. Abrasion-resistant aluminum coatings were also developed that significantly improved the retention of reflective properties of the aluminum coating over longer periods of time. Test garments containing the improved cloth were worn by the crash rescue crews of both the Naval Air Station, New York, and the Naval Air Station, Norfolk, Virginia, for a period of fifteen months. Results from the field evaluations confirmed laboratory test data which showed the ability of the abrasion-resistant finish to retain its heat reflective properties for longer periods of time than the aluminum coating on the glass/asbestos fabric. The 1.2-pound, asbestos fabric proved to be more durable than the 11-ounce, glass/asbestos fabric and test subjects indicated that they would willingly accept the added weight. During this test period, it was felt that the use of a separate vapor barrier would offer advantages in the test garments, since it was thought that the integral neoprene coating on the 11-ounce glass/asbestos fabric contributed to reduction of the tear strength and increased susceptibility to edge abrasion.

Based on the reported results confirming the improved durability of the aluminum coating and basic asbestos fabric and user acceptability of garments made from this fabric, NCTRU concluded that a neoprene coating applied to the back of the improved fabric should be investigated for use in shipboard coveralls.

Coveralls containing the improved neoprene-coated, aluminized, asbestos fabric (Figure 2) were worn by firefighters aboard two aircraft carriers, the USS AMERICA (CVA-66) and the USS SARATOGA (CVA-60), and at the Naval Damage Control Training Center, Philadelphia, Pennsylvania, and the U. S. Naval Schools Command, San Francisco, California (8, 9, 10 and 11, respectively). Questionnaires sent with the test garments did not specifically request comments on the durability of the improved cloth as compared to the glass/asbestos cloth. However, comments from both the aircraft carriers and the Naval firefighter training centers were in agreement that the test coverall is an improvement and a satisfactory replacement for the glass/asbestos coverall. Reference 8 states that, in general, the experimental outfit was superior to the neoprene-coated, aluminized, glass/asbestos Navy suit. The reflective qualities were far superior. References 9 and 10 are in agreement that the improved outfit was satisfactory to replace the glass/asbestos clothing, and reference 11 comments that there was considerable improvement over the glass/asbestos clothing.

As previously discussed, it was felt that an integral coating on the aluminized asbestos cloth might increase its stiffness, reduce its tear strength and require an excessive weight of neoprene to meet minimum

water-resistance requirements. For the current development program, therefore, a laboratory evaluation was conducted on five sample lots of coated fabrics. Results of the more important physical properties are discussed in the following paragraphs (see also Tables I, II, and III).

Stiffness

Stiffness of the neoprene-coated, aluminized, asbestos fabric may be affected in the effort to meet its many operational requirements. Two of these are non-flammability and protection of the firefighter against steam burns. Accordingly, stiffness values between fabrics can vary if the manufacturers decide that to produce acceptable fabrics they must increase the neoprene-coating weight and/or add a fire-retardant finish to the basic cloth. Stiffness values can also be affected by poor manufacturing controls of the laminating process (heat, pressure and time), use of abrasion-resistant, aluminized, plastic films, and changes in type and weight of bonding adhesives.

Table I shows stiffness values of the selected fabrics. The standard, aluminized, 1.2-pound, asbestos cloth has a maximum stiffness requirement of 0.055 inch-pounds for the warp and filling (6). Fabrics F and G exhibit moderately low stiffness values. Values for Fabrics A and B are 0.051 x 0.047 and 0.032 x 0.034 inch-pounds, respectively. The two, aluminized, plastic-film fabrics, D and E, exhibit fairly close values in the warp and filling of 0.056 x 0.063 and 0.068 x 0.056 inch-pounds. While stiffness values for Fabric C are relatively high, it should be noted that Fabric C contains a fire-retardant finish and a neoprene-coating weight of 7.7 oz/yd^2 which contributes to the higher values.

Based on the analysis of laboratory data and current manufacturing techniques, the higher stiffness values realistically indicate the practices of fabric manufacturers.

Water Resistance

Minimum water-resistance requirements of 30 psi initially and of 25 psi after low-temperature and adhesion-of-coating tests were established for Fabric F used in the shipboard coverall (3). Table II shows water resistance for the selected fabrics. Fabric F exhibits 110 psi initially, 77 psi after low-temperature tests and 42 psi after adhesion-of-coating tests. (The use of fine-glass yarns in a tight plain-weave construction permits the use of a minimum weight of neoprene coating.) The very high values exhibited by Fabrics D and E can be directly attributed to the impermeable plastic film employed to retain a high degree of reflectivity after abrasion. All aluminized, plastic-film laminates will exhibit extremely high water-resistance values. Therefore, the problem of meeting the minimum water-resistance of 30 and 25 psi is confined to Fabrics A, B, and C employing Method I aluminization and not to fabrics containing the plastic-film laminate. Analysis of Table II data indicates that a neoprene coating weight of 4.1 oz/yd^2 for Fabric A permits adequate water resistance. Fabric C, with a 7.7 oz/yd^2 coating weight, also meets the minimum requirements, but it exhibits a lower water-resistance value than Fabric A. Fabric B did not pass a 25-psi minimum after low-temperature and adhesion-of-coating tests, but showed values of 14 and 15 psi, respectively.

In view of the limited data shown in Table II, a maximum coating weight of 8.0 oz/yd^2 should be considered for the fabric selected for use in shipboard coveralls.

Tear Strength

It was originally visualized that there would be a significant reduction in tear strength when the neoprene coating was applied to the back of aluminized asbestos fabrics. It is well known that the tear strength of fabrics are compromised when the yarns within the fabric structure are restricted from moving freely.

Table III shows, however, that the values exhibited by Fabric G and Fabrics A through E are fairly uniform with only slight differences in tear strength. Analysis of these values indicates the following facts. The adhesive coating, used to bond the aluminum coating to the base fabric, has restricted the movement of yarns within the fabric and caused an initial loss in tear strength (The tear strength of the basic asbestos fabric without aluminization is about 11.9 pounds x 9.9 pounds while the aluminized asbestos cloth shows values of 9.9 pounds x 8.7 pounds (2)). The addition of a neoprene coating to the back of the aluminized fabrics does not continue to significantly reduce the tear strength (Table III).

Fabric F shows the effect on tear strength of the all-glass warp as compared with the glass/asbestos filling. The all-glass warp exhibits a value of 3.8 pounds while the filling has a value of 9.3 pounds. It can be assumed that, if the warp also contained glass/asbestos yarns, its tear strength would be equally as high as that of the filling with a corresponding increase in garment durability.

Variables Affecting Final Weight of Fabrics

Fabrics A through E varied in weight in accordance with the weights of the basic fabric, aluminum coating, neoprene coating and fire-retardant finish. The basic asbestos fabric is designated by industry to weigh 19 oz/yd^2 $\pm$ 7%. This tolerance is not always maintained, however, and basic fabrics have been manufactured that weigh as high as 22 oz/yd^2. The aluminum surface, a vacuum-deposited coating, should have no effect on the final weight. A change in weight, however, can be expected according to the amount of adhesive used. If it is used in conjunction with a plastic film overlay, the adhesive, not the 1/4-mil plastic film, produces the major variation in weight of aluminum coating systems. As a result, the weight of the aluminum coating between fabrics could differ by about 1.5 oz/yd^2. Neoprene coating has a greater potential for weight variation. Data indicated that a coating weight of from 4 to 7.7 oz/yd^2 should be anticipated. Additional weight of about 2 oz/yd^2 can also be expected if the basic fabric is treated with a fire-retardant finish.

When the maximum weight requirement for the coated fabric is considered, the lightest weight possible would be most advantageous. Table III data show an acceptable weight of 29.6 oz/yd^2 for Fabric C; therefore, 30.5 oz/yd^2 could be considered a standard, maximum, finished weight.

Additional Fabric Characteristics

Data in Table III show additional constructional features and physical properties of the selected fabrics. Fabric F failed the reflectivity-after-abrasion test because it did not have a durable abrasion-resistant aluminum coating, while Fabrics A through E and G had abrasion-resistant coatings and passed the reflectivity test.

As used in Table III, crazing refers to the thin lines observed through the flexed portion of the aluminized surface at low temperature when the adhesive is not cracked and the basic fabric not exposed. The observed crazing should not compromise the heat protective qualities or reduce the use-life of aluminized fabrics. However, cracking of the aluminized coating, exposing the basic fabric, is unacceptable and is cause for rejection.

CONCLUSIONS AND RECOMMENDATIONS

A neoprene coating was successfully applied to the back of an aluminized, 1.2-pound, asbestos, herringbone-twill cloth (Fabrics A through E) with demonstrated ability to significantly improve the use-life of firefighter's garments. As shown in previous testing and evaluation, this aluminized asbestos cloth possessed good durability of the basic cloth and good abrasion resistance of the aluminum coating. More recent laboratory evaluation of the neoprene-coated, aluminized cloth showed it to exhibit acceptable weight, stiffness, water resistance and tear strength. A limited user evaluation of further coveralls indicated that it was satisfactory (exhibiting good sewing characteristics). Accordingly, the neoprene-coated, aluminized, 1.2-pound, asbestos cloth is considered a desirable replacement for the neoprene-coated, aluminized, 11-ounce, glass/asbestos fabric for use in shipboard coveralls. In view of its relatively high weight, however, further studies are recommended to develop lighter substitutes.

APPENDIX A. ILLUSTRATIONS

Figure 1 - Worn coat containing aluminized, neoprene-coated glass/asbestos fabric to show poor durability of basic fabric and aluminum coating

Figure 2 - Shipboard coveralls containing recommended, aluminized, neoprene-coated, 1.2-pound, asbestos fabric

APPENDIX B. REFERENCES

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